

# LARGE MOTOR INSTALLATION AND STARTUP

by

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*William H. Miller founded REM Technologies, Incorporated, in 1984. He serves as President and Principal Engineer. REM Provides numerous engineering services to motor and generator users.*

*Mr. Miller graduated from Cornell University as a Mechanical Engineer. He joined the Elliott Company, as a Development Engineer, and concentrated on the analysis of bearings, seals, and rotor vibrations. This work gained him his first patent award for*

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*In 1976, he joined Ingersoll Rand Company. While there, he was a co-author on a paper and was awarded the American Society of Lubrication Engineer's Walter D. Hodson Award. Mr. Miller later joined Mechanical Technology, Incorporated in Latham, New York, where his research and development in the area of compliant foil bearings produced four new and patented designs to improve foil bearing performance.*

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## ABSTRACT

The installation tasks and startup considerations necessary to commission large electric motors are discussed. The tasks are discussed in the usual installation sequence, but some series of tasks may need repetition if the adjustment of one part affects an earlier adjustment. When connecting to other machinery, confirm that the installed machinery is properly mounted before attempting to align or grout the motor or generator. Particular attention must be taken in the alignment of machines for direct drive.

## INSTALLATION OF ASSEMBLED MACHINES

### Tasks

- Lifting and handling
- Unpacking
- Set machine on foundation
- Level base
- Align base with respect to connected machinery

- Align bearing pedestals and set endplay
- Align couplings
- Check drive coupling alignment
- Set air gap
- Install ventilating and accessory parts
- Make final check of alignment
- Dowel bearing pedestals
- Grout base
- Make electrical connections
- Make initial start, inspection and adjustments
- Check centering of rotor (running endplay)
- Dowel stator frame
- Couple to driven apparatus
- Startup

## LIFTING AND HANDLING

Machine parts should be handled carefully by personnel experienced in lifting and moving heavy equipment. Lifting slings should be in good condition and be padded where contact is made with finished machine surfaces. A spreader bar should be used where lifting cables might otherwise crush the top edge of a part or packing case.

Before attempting to lift any machine, check the outline drawing for the lifting points and their limitations. Unless otherwise specified on the outline drawing, eyebolts, lugs, etc., are intended to support *only* the part to which they are attached. These devices are not suitable, in general, for lifting the total weight of the assembled machine. Failure to observe these precautions may result in damage to the equipment, injury to personnel, or both. Parts should be level when lifted. In some cases, the lifting device (eyebolt, lug, etc.) cannot be located directly above or online with the center of gravity, and auxiliary slings will be required to level the load.

Some machines may be handled as an assembled unit. If so, the outline drawing will note the location capability of provisions to lift the entire assembled unit. Assembled units should be handled in one piece by attaching a sling (or slings) to the lifting lugs on the base, as indicated on the outline drawing. The outline drawing will also show the position of the lifting lugs. Assembled units should *not* be handled by attaching slings to the shaft, to the bearing pedestals, or to the stator frame.

A machine assembled on a base must always be supported with blocks at each bearing pedestal and stator foot. The supports should keep the base level and flat, and must elevate the base so that the stator (or any stator part) does not support any portion of the weight of the machine. Slings must never be wrapped around the rotor core or journals. A spreader bar or blocks should be used to prevent the slings from bearing against the windings. Blocks, if used, must bear on the rotor hub or spider, not on the windings.

The preferred method of supporting a rotor, other than in its own bearings, is to use stands. Blocks or heavy timber cribbing may be used if stands are not available. Whatever the support, provisions should be made to prevent the rotor from rolling off the support, and wooden pads should be used on the steel stands to avoid marks on the machined shaft surfaces. The bearing journals should *not* be used as a location for the supports when the rotor is set down, and they must be protected during handling.

An alternate method of setting down a rotor is to support the rotor core with a padded cradle shaped to conform with the curvature of the core. The length of the cradle must be longer than the iron of the core, and when supporting a rotor, the cradle must be centrally positioned under the iron core to avoid application of pressure to the end connections of the armature winding. The width must be at least one-fifth of the rotor diameter, but a greater width may be desirable to prevent the rotor from rolling.

In no case shall the rotor be stored for any length of time by supporting the rotor in a cradle, since permanent damage to the core may result. This method should only be used during handling of the rotor. Rotors should always be lowered slowly and carefully into the cradle with axis of the shaft parallel to the rails of the cradle to avoid damage from impact and point load.

Stators can be lifted as an assembly by the lifting lugs, if so stated on the outline drawing. On larger machines, a spreader bar should be used to obtain a vertical pull on each sling to avoid any deformation of the frame.

Bases should be lifted by slings around the entire beam section. The gussets between the top and bottom flanges are not designed to serve as lifting lugs and should not be used for lifting. The supports used during lifting should be so chosen as not to distort the base.

## UNPACKING

If the machine or machine parts have been exposed to a low temperature, do not remove their coverings until they have had sufficient time to attain a temperature that is nearly as high as that of the room in which they are to be unpacked and located. Otherwise, when opened, moisture will condense on the cold parts. This may reduce the electrical resistance of insulations or cause rust or corrosion of metallic parts. If the machine is shipped disassembled, experienced personnel should check all journal and bearing surfaces and repair any damage resulting from mishandling or unprotected storage.

During shipment, the rotor of an assembled unit is restrained in the axial direction by a temporary shipping device which clamps the end of the shaft to the bearing pedestal. In the case of a single-bearing machine, or section of a unit which is split for shipment and without a bearing on one end, the shipping device is mounted on the base and arranged to support the shaft and to provide a clamp for constraint of axial movement. The shipping device must be removed during installation when the machine is in place or (for single-bearing units) when the shaft can be supported by the mating shaft. When the shaft is clamped to a bearing pedestal, the pedestal is doweled to the base with steel dowels. The machine or machine parts should be inspected for dirt and foreign material which may have accumulated during shipment and/or storage. Particular attention should be paid to ventilation ducts, spaces between poles, windings, and the spaces in the stator and spider fabrications. Dry rags (no solvent) together with low pressure (35 psi maximum), high-volume dry air is recommended for this cleaning. The direction of air flow must be carefully controlled to avoid blowing foreign material into places even less accessible.

## BASES AND FOUNDATIONS

All load-bearing portions of bases must be evenly supported during the installation of a machine and, except for self-supporting

bases, the entire base acts only as a spacer between the machine and the foundation. Bases ordered and designed to be self-supporting should be so designated, and mounting requirements should be shown on the outline drawing. Self-supporting bases are shipped assembled and may be placed directly on a level foundation.

Bases of smaller machines are furnished as a single fabrication which can be placed on the foundation without further assembly. Larger machines and M-G set bases are built in sections to comply with shipping or handling requirements and must be bolted together after preliminary placement on the foundation. Joints between mating sections should be aligned in the factory, adjacent sides marked, and the joint doweled to simplify reassembly during installation.

Usually, steel pads, each with two threaded holes, are located inside the base, one at either side at each end of the base. These pads are to facilitate attachment of the electrical grounding cables to the machine in order to bring the machine exterior parts to a safe ground potential. Before the grounding cables are bolted onto the pads, the pad surfaces must have paint or rust removed by light sanding or grinding so a good electrical contact can be achieved. Consult the machine outline drawing for pad location, thread size, and recommended grounding cable sizes.

Foundation caps are heavy cast iron or structural steel members used in place of a base to distribute the weight of a stator foot or bearing pedestal over a larger area of the foundation, thereby reducing the stress in the foundation. Since the load-bearing parts of the machine are independently supported by separate foundation caps, lateral position as well as vertical position of the machine parts must be maintained by the foundation. Like bases, foundation caps must be evenly supported by the foundation during installation, and continuously supported, i.e., grouted, during machine operation.

The foot bolts holding the stator and bearing pedestals to the base of machines shipped assembled are temporary, if the outline drawing shows a foundation bolt extending up through the hole in the base and the foot. The temporary bolt should be removed just prior to lifting the assembled machine over the foundation to lower it in place on the foundation bolts.

## ALIGNMENT

The base should be initially positioned to provide as accurate an alignment as possible with the connected machinery. The base should be used to best divide the shaft endplay between both ends of the controlling bearing to minimize movement of bearing pedestals during final alignment. Base centerlines and bearing-pedestal mounting-bolt patterns may be used as a guide. The preliminary alignment of all bases for machines having three or more bearings may be checked by installing the pedestals and measuring to the bearing rocker seat using a laser optical system.

## LEVELING

A high-grade, sensitive spirit level may be used to level small bases which can be spanned by the level. Larger machines should be leveled with a precision laser optical system. Sighting techniques should be used which minimize instrument and systemic errors.

A base warped or bent through improper handling may not rest firmly on all supports with only the force of its own weight. It may be necessary to assemble part or all of the machine on the base to provide the additional weight needed to bring the base to the proper level for alignment.

As an alternate procedure, the foundation bolts may be used to pull the base to the leveling plates, grout pads, or other supports. The base should first be aligned as accurately as possible, and the bolts should be centered in the bolt holes. The foundation bolts may then be anchored securely with grout. However, this grout

should not restrict subsequent leveling and alignment of the base. The foundation bolts should then be tightened and worked against leveling screws or shims to level the base.

## GROUTING

Before grouting the base, it is recommended that the machine assembly and final alignment be completed and rechecked. *Grouting must be completed before operating the machine.* If the grout is prepared at the site, a cement/sand ratio of 1:2, with only enough water to give a stiff mixture, is recommended.

If a commercially available grout mixture is used, the mixture should be of high quality and mixed in accordance with supplier's instructions. A rich, high-grade, nonshrink grout is recommended for the space underneath the flanges and ribs of the base, and a common cement grout is recommended for the space at the side of the base within base box sections. To avoid any subsequent expansion of the nonshrink grout, the exposed surfaces should be sealed with either paint or at least one inch of common cement grout.

The surface should be clean, rough, and thoroughly wetted, but with free moisture removed. The grout should be rammed or puddled under the base from only one side, and the surface of the grout emerging from the opposite side should be removed and discarded. Where the base is fabricated as a box section, the ribs should be supported on a ridge of nonshrink grout and the balance of the box section filled, through the access holes provided in the top of the base, with common cement grout. Grout, especially nonshrink grout which can be set within 20 minutes, should be placed quickly to avoid working the grout after it starts to set. Adding water to prolong the working time is not recommended.

Work the grout into all space up to and flush with the top surface of the base, including spaces in foundation bolt holes which are not filled by the eyebolt. Voids should be prevented. If the foundation does not extend upward beyond the bottom of the base, provide lateral support and cover the non-shrink grout under the base flanges. To accommodate the thermal expansion of the steel base, expansion material should be added to prevent foundation cracking at the bottom of the curb. Voids should be prevented.

If a vibrator is used to move and settle the grout, it can cause segregation of the components of the mixture and should be used sparingly and with discretion.

## CENTERING OF STATOR ON ROTOR

Airgap and end play adjustments should be made to ensure that the stator is properly positioned with respect to the rotor. This is usually done by shifting the stator until the location is correct. After these adjustments, the stator should be secured to the base with dowels. All pedestal and stator dowels should be in place before the machine is operated under load.

## RADIAL CENTERING (AIR GAP)

After the rotor, shaft, bearings and coupling have been aligned, the stator should be positioned so that the rotor is centered in the stator. Some frames have tapped holes in the footplates to permit raising the frame with bolts bearing on the base. This facilitates insertion or removal of shims from under the frame feet. Bolts used to jack the frame should be removed after shimming and should *not* be used as permanent support.

The radial "iron-to-iron" air gap is the distance from the circumferential center of the pole face to the face of the rotor. It can be best measured with a tapered gage and a fixed block gage, both on extension handles long enough to reach the iron without interference with the end turns. The tapered gage should be chalked, the block gage positioned on the rotor iron, and the tapered gage pushed firmly between the block and the stator iron. Read the

tapered gage at the point of maximum penetration, as indicated by the undisturbed chalk.

To obtain consistent results, the gage insertion force must be the same for all measurements. A uniform air gap, measured from one location on the armature surface by rotating the armature to four or six points, spaced as equally as possible around each end of the rotor circumference, is usually sufficient to ensure correct radial centering of the rotor. The gap variance can be expected to be within 0.02 in for a large machine. Repeat the procedure for the opposite end.

## AXIAL CENTERING (RUNNING ENDPLAY)

The total endplay of a rotor is established by the end-clearance at the controlling bearing. However, the magnetic force tending to axially center the rotor in the stator will, if the stator is not correctly located with respect to the pedestals, cause the end of the journal to ride or oscillate against the controlling bearing. With the stator located correctly, the magnetic forces should hold the rotor within the center one-third of the endplay, known as running endplay. Before adjusting running endplay, it is essential that the shaft be leveled and, with fields de-energized and the rotor turning, float freely in the axial direction and assume no preferential position. That is, the shaft should continue to operate at any axial position without shifting of its own accord. The rotor of a motor operating at weak field condition may be pushed in an axial direction by the pressure of the ventilating air. The magnetic centering force may be insufficient to counterbalance this force. The force thus being exerted on the control bearing is small, and the bearing is normally designed to handle this minor thrust intermittently.

While running with the specified volume of ventilating air flowing through the machine, the axial operating position of the shaft should be observed. If the operating position is not within the center one-third of the endplay, the stator should be shifted axially in the direction toward which the rotor must move to be centered in the endplay. Check the radial air gap and readjust, if necessary, then tighten the frame hold-down bolts and again check running endplay. When satisfactory running endplay and radial air gap are obtained, the frame should be secured to the base with dowels.

Machines which are connected through a flexible coupling to equipment having an axially fixed shaft should have the running endplay adjusted when the machine is uncoupled. When coupled and running, the shaft position should be checked and corrections should be made if a journal end is "drawn" to the bearing by the coupling. Machines which are connected through a solid coupling to equipment having an axially fixed shaft should have the rotor core centered in the stator core by measurement from a reference point on the shaft and stator, such as a shoulder or flange. When determining the center of the core, do not include the end connections that extend beyond the iron of the core. While the mechanical center may not correspond precisely to the magnetic center, the thrust developed by any offset will be small and should not significantly add to the axial force on the fixed shaft. If necessary, the axial alignment may be refined after running the unit.

Windings should be checked, and any damage to the insulation system, especially on end-turns, should be repaired.

The insulation should be tested and evaluated using a 500 volt DC supply. The supply of the test potential should be current-limited to avoid damage to insulation having a low insulation resistance. The insulation resistance, while not a definite measure of the dielectric strength of the insulation, is a useful indication of the suitability of an insulation for operation or for further test at an over-potential.

The resistance of any electrical insulation varies with the test potential, the insulation temperature, moisture (in or on the insulation), surface condition, and age. For a given test potential and

with known insulation temperature, the result of an insulation-resistance test is thus dependent on the winding surface condition and age as well as moisture content. The insulation-resistance data must be properly interpreted to be of value. Each machine at each installation will have an insulation-resistance history that is characteristic of the particular machine and is helpful in deciding the timing of corrective maintenance. It is recommended that insulation resistance be measured and recorded each month.

For more information on the general theory, limitations and use of insulation-resistance measurements, and the methods of obtaining data, refer to the latest revision of the Institute of Electrical and Electronics Engineers (IEEE) Standards, Publication No. 43, "Recommended Guide for Testing Insulation Resistance of Rotating Machinery."

The duration of application of a test potential should be one minute for an insulation-resistance measurement. Insulation-resistance meters of the hand-cranked, generator type provide a convenient, readily-portable method of obtaining an approximate measurement; however, an electrically powered meter or measuring circuit is recommended to provide the accuracy needed for consistent periodic measurements made during the service life of the machine. A correction factor should be applied to any insulation-resistance value measured when the insulation temperature is other than 40°C.

## BEARING AND BEARING PEDESTAL INSULATION

The insulation resistance of each insulated bearing pedestal should be periodically measured and the insulation corrected if the resistance is less than 20,000 ohms, as indicated by a 500 volt d-c insulation-resistance meter.

The shaft insulation of motors and engine-driven generators is checked by measuring the insulation resistance of each insulated bearing. The pedestal cap and upper bearing half is removed and the shaft jacked to clear the lower bearing half. Measure the insulation resistance of both upper and lower bearing halves. If the lower bearing half shows low resistance, it may be necessary to either slip a piece of clean, nonconducting paper between the bearing and the journal, or roll the bearing out of the pedestal in order to measure only the resistance of the bearing insulation.

After reassembling the bearing and pedestal cap, insert a thickness gage between the shaft and the pedestal shaft seal and slide the gage around the shaft. All metal parts should clear the shaft by 0.010 in to 0.015 in.

## ELECTRICAL CONNECTIONS

Before connections to the power and control systems are made, the windings should be checked for insulation resistance and, if the resistance is low, the windings should be cleaned and/or dried. Main motors should be checked for proper direction of rotation before coupling to the driven equipment, especially if the equipment may be damaged by incorrect rotation. Auxiliary motors (blower, oil pump, etc.) should be checked for proper rotation before starting the main motor or generator.

Space heaters, inspection lights and electric outlets, as furnished, should be wired to a source of power of the voltage and frequency specified on the outline drawing. The space-heater circuit should include a switch, either manual or automatic, to turn on the heaters whenever the machine is shut down.

Thermal-sensitive switches (if furnished) are wired to a common point, as shown on the outline drawing. The terminals are marked with a letter followed by a subscripted number to identify the particular switch. Resistance temperature detectors, if furnished, are wired to a special terminal board. Connections to this terminal board are usually described on the outline drawing.

## GROUNDING

Motor or generator and control wiring, overload protection and grounding should be in accordance with the National Electric Code and consistent with sound local practices. Failure to observe these precautions may result in damage to the equipment, injury to personnel, or both. The ground conductor size should be selected to safely carry the maximum fault current available from the source for the time required to interrupt the fault current. Refer to the outline drawing for recommendation.

## INITIAL STARTING

### *Prestart Inspection*

The following are suggested as some of the items which are most frequently overlooked and which should be checked before starting a machine for the first time, or after an extended shutdown.

- The voltage on the nameplate corresponds with the line voltage.

- The journal packing has been removed (on machines shipped assembled); bearing-pedestal insulation has been checked; the oil scraper or rings are in place; the journal, bearing-pedestal and oil lines have been properly cleaned; and joints and oil plugs are sealed and tight.

- Oil level in all bearings is correct. All necessary oil and water piping is complete and operative, and the check valve in the bearing lift-pump pipe, where used, is installed and is functioning properly. Pour a pint of oil into the bearing through the inspection opening immediately before start, so the bearing will not start up dry. Oil viscosity is correct for the application.

It should be recognized that certain limitations in sleeve-bearing speeds are necessitated by the hydrodynamic process in the bearing. The oil film between the shaft journal and the bearing necessary to prevent a "dry", i.e., metal-to-metal contact, bearing operation can only be developed and maintained above a certain minimum bearing rotational speed. This minimum speed is a function of the bearing load, the oil viscosity and the bearing configuration. Failure to develop the oil film will result in bearing wipe.

The motor outline drawing usually specifies the permissible minimum operational speed for the particular unit and the required oil viscosity necessary for the operation. Below this minimum speed no lubricating-oil film can be maintained with the specified oil viscosity, and bearing wipe can be expected to occur. If it is desirable to run below the minimum speed for any length of time, oil with higher viscosity is required or the bearing should be supplied with a bearing lift pump, which automatically lifts the bearing journal and supplies oil between the journal and the bearing at speeds where the hydrodynamic lubrication cannot exist.

For the reasons listed above, motors and generators with sleeve-type bearings should be brought up to speed as quickly as possible, unless they are equipped with bearing lift pumps. It is also recommended that motors which, for some reason, are to operate at minimum speed for extended periods of time be brought up above appropriate minimum bearing speed, e.g., to base speed, and run for some time to assure a well-oiled bearing operation. If the bearing oil is replaced by oil of higher viscosity than that recommended on the outline drawing, at the maximum operational speed excessive bearing temperatures may be realized, which may damage the bearing.

- The interior of the stator frame, the rotor, the air gap, and the spaces between the poles are clean and free of loose objects (bolts, nuts, and tools).

- All moving parts have sufficient clearance from the nearest stationary parts, especially between the pole faces and the stator. Carefully turning the rotor with a crane to check for interference is recommended.

- All electrical clearances are in good condition, particularly where bare conductors of opposite polarity approach each other. Bend all brush pigtails to maintain adequate clearance from grounded portions of the machine and from pigtails or bus bars of opposite polarity.

- All bolts and nuts are tight and locking devices are positively secured. Foundation bolts, frame, and bearing hold-down bolts are tight. All frame and bearing-pedestal (or bracket) dowels are installed. Steel shipping dowels are replaced with insulated dowels where necessary and dowels installed in all bearing pedestals and stator frames.

- All protective devices (over speed devices, bearing temperature relays, etc.) are connected and function properly.

- All electrical connections are in accordance with the wiring diagram. Motor rotation is correct.

- Controller and protective relays are wired correctly and function properly.

- The cooling and ventilating system provides the specified quantity and quality of ventilation per the outline drawing. Covers, inspection doors, and access doors of force ventilated machines are subject to substantial airflow forces. Use caution when removing and replacing covers or when opening and closing access doors when machine is rotating or energized or when ventilating fans are operating.

When the machine has been carefully inspected according to the instructions outlined above, make the initial start by following the regular sequence of starting operations given under the instruction for the particular type of machine.

## NO-LOAD INSPECTION

Check the bearing lubrication. If the bearings require cooling oil, or if flood lubrication is used, the pumps should be running and

oil circulating. If oil-pressure starting is used, the pump should be turned off when the machine is running. During the first several hours of continuous operation, the bearing temperature should be checked frequently. Maximum safe operational temperature should not exceed 80°C.

- Check for undesirable rubbing interference, and correct if found.

- Check the vibration amplitude at all operating speeds. Correct by balancing or realignment, if necessary.

- Check the running endplay, and dowel the frame before loading the machine.

- Operate the unit at no-load for a time sufficient to detect and eliminate any excess heating.

## CONCLUSIONS

Careful handling, proper inspection of all components, and diligent attention to every detail are required to ensure the successful installation and startup of large machines. The outlined step-by-step procedures should be followed and all manufacturer instructions adhered to. Prepared checklists should be in place and each item logged as it is completed. These guidelines are also largely applicable to machines that have been sent out for repair or reconditioning. When being reinstalled, items already in place should be rechecked, looking for signs of deterioration or damage that may have been incurred during removal.

The production of an entire facility is often dependent upon the reliable operation of large motors. If shortcuts are taken that result in less than attainable reliability and performance, the possible loss of product through unscheduled outages or reduced capacity will soon offset any short term savings. The need to be competitive requires that the best effort be expended for every task involved.

